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(54) **METHODS AND APPARATUS FOR SECURING MULTI-PIECE NOZZLE ASSEMBLIES**

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(58) **Field of Search** 29/889.21, 889.22; 415/200, 191, 209.2, 209.3, 209.4, 210.1

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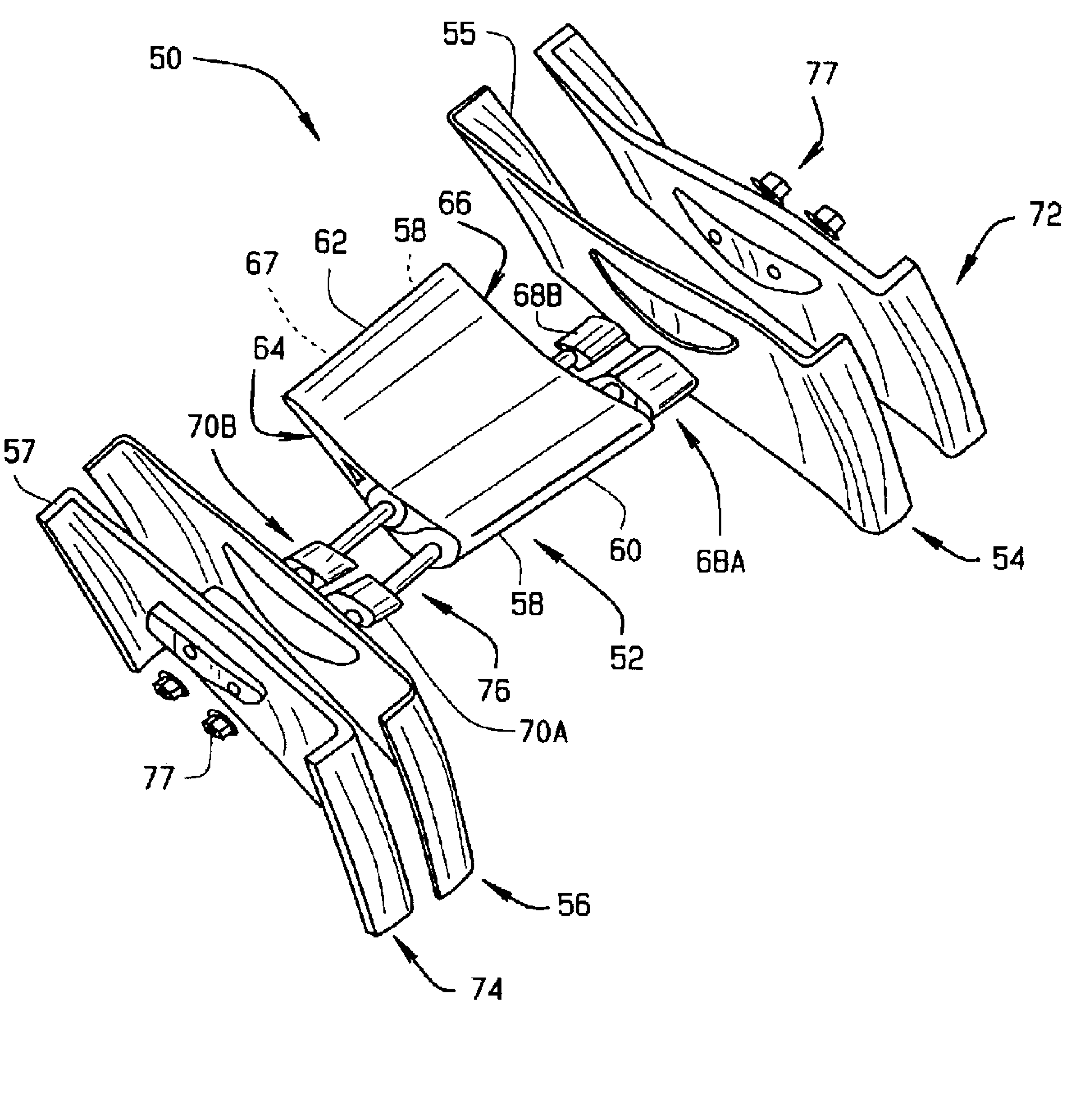
(57) **ABSTRACT**

A method for securing a nozzle for a turbine is provided. The nozzle includes an airfoil having a suction side and a pressure side connected at a leading edge and a trailing edge such that a cooling cavity is defined within the airfoil, the airfoil extending between an inner band and an outer band. The method includes extending at least one member through the airfoil, and at least one of the inner band and the outer band. The method further includes securing the nozzle assembly in position with at least one fastener such that the at least one member is coupled adjacent to at least one of the inner band and the outer band.

18 Claims, 5 Drawing Sheets



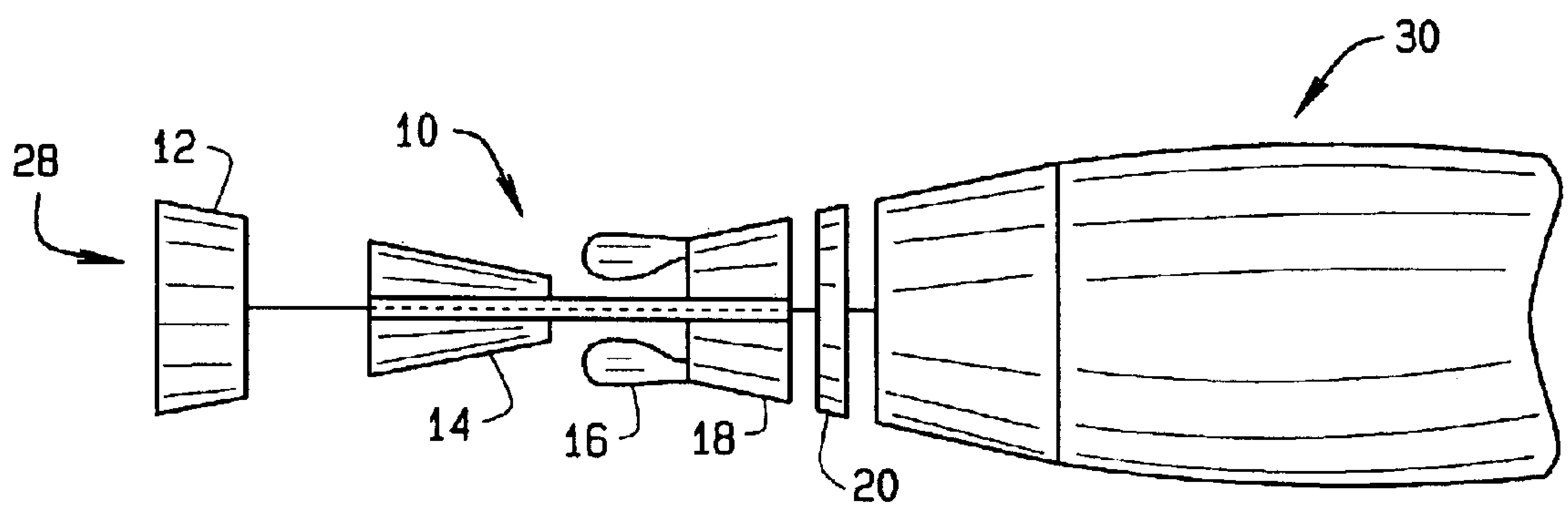


FIG. 1

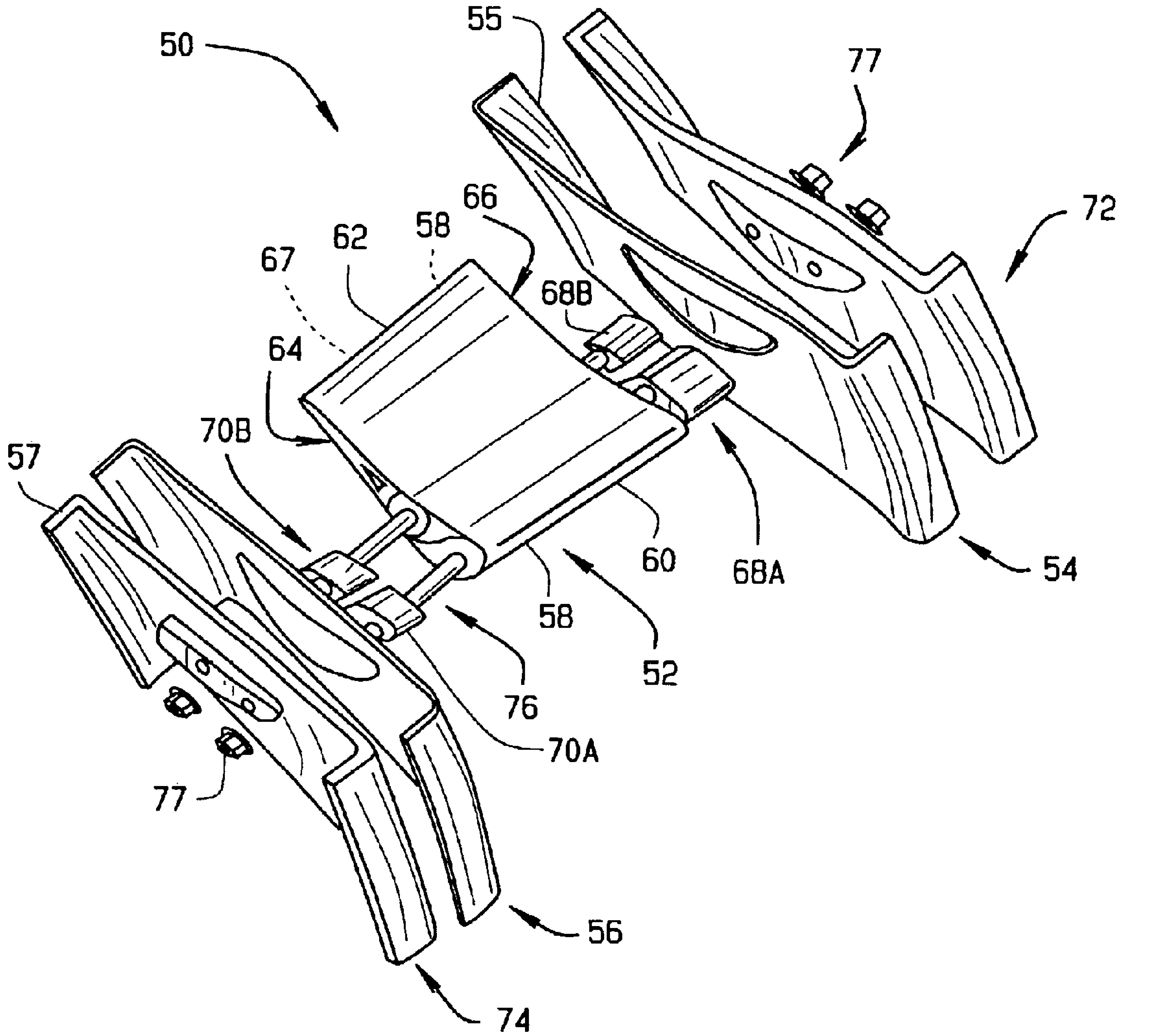


FIG. 2

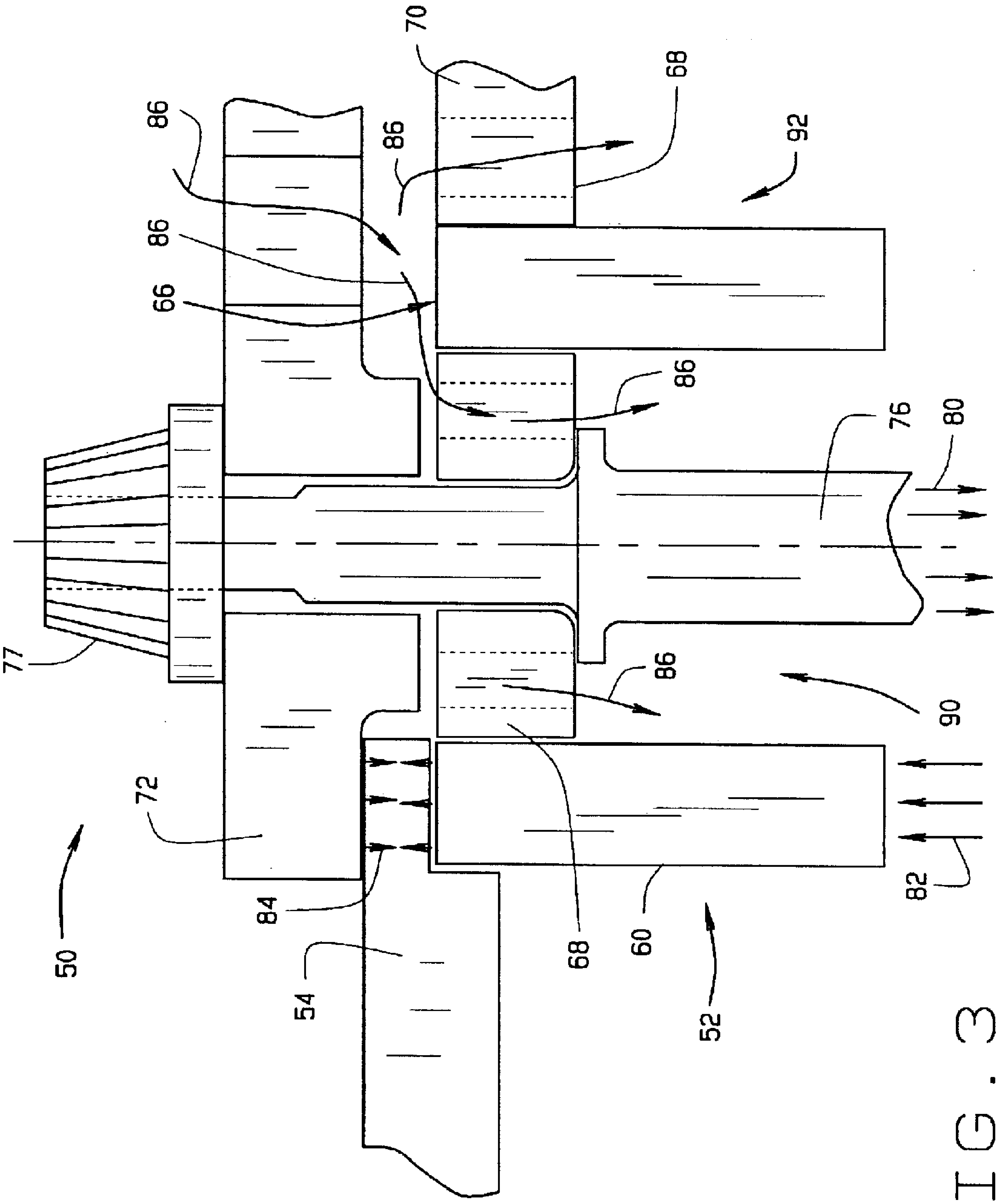


FIG. 3

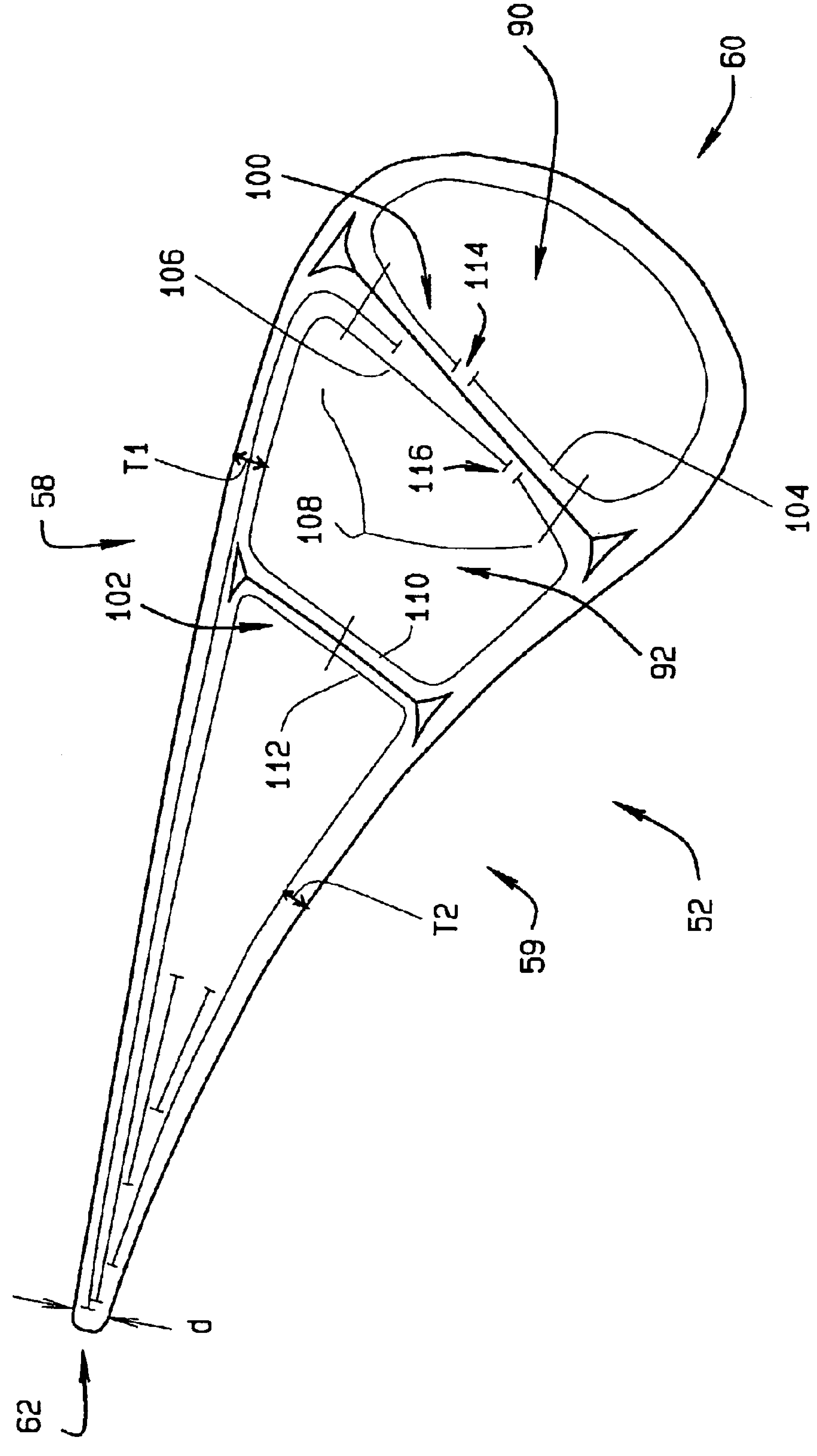


FIG. 4

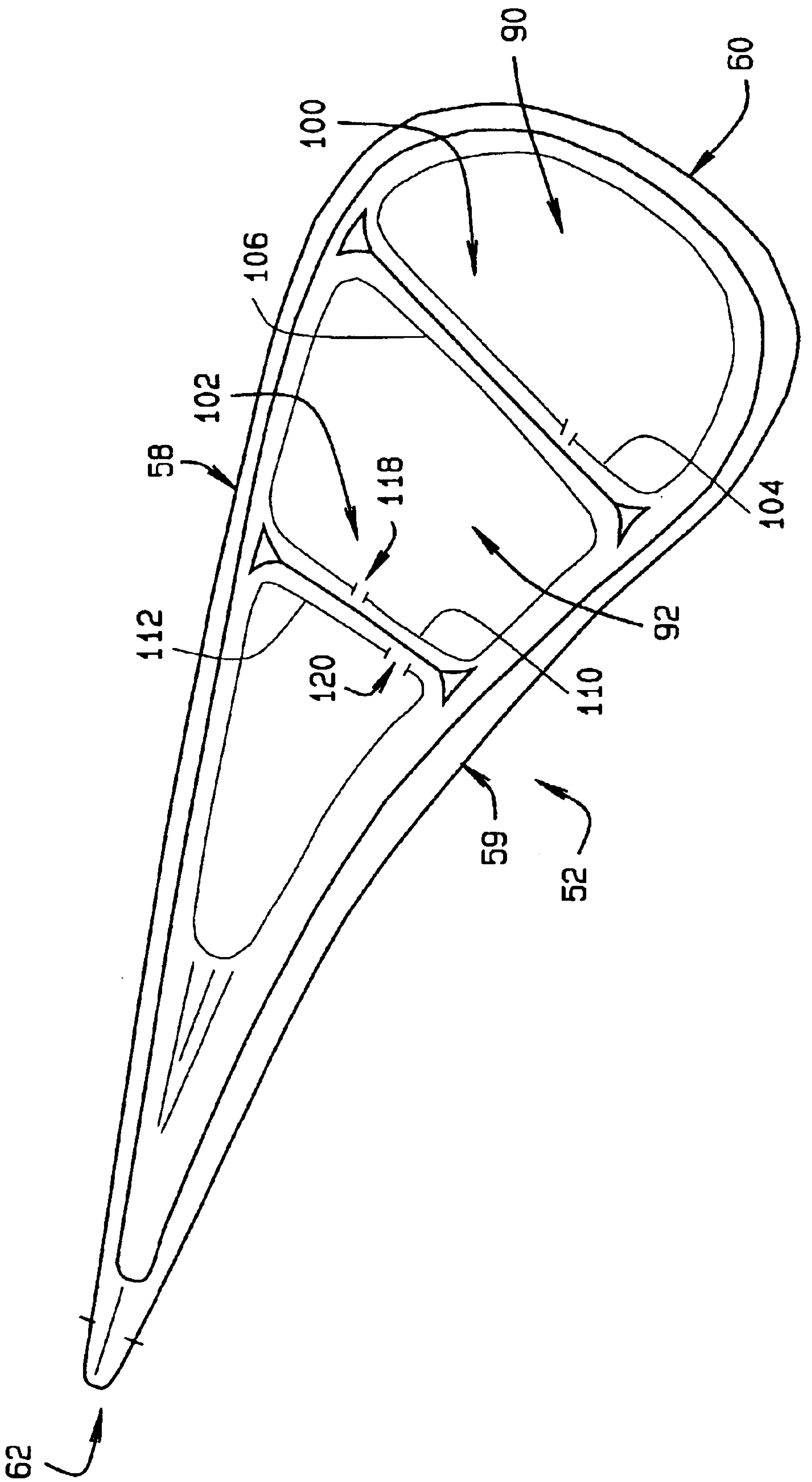


FIG. 5

METHODS AND APPARATUS FOR SECURING MULTI-PIECE NOZZLE ASSEMBLIES

BACKGROUND OF THE INVENTION

This invention relates generally to turbine engine nozzles and more particularly, to methods and apparatus for securing multi-piece nozzle assemblies.

At least some known turbine engines include a turbine nozzle assembly which channels flow towards a turbine. At least some known turbine nozzle assemblies include a plurality of nozzles arranged circumferentially within the engine. Each nozzle includes an airfoil vane that extends between inner and outer band platforms. Each airfoil vane includes a pair of sidewalls that are connected at a leading edge and a trailing edge.

During operation, the nozzles are typically cooled by a combination of internal convective cooling and gas side film cooling. Typically, the metal temperature distribution of a vane airfoil is such that the trailing edge is significantly hotter than a temperature of the bulk of the airfoil. The temperature gradient created may induce compressive stresses at the vane trailing edge. The combination of such stresses and temperatures may result in the vane trailing edge being the life limiting location of the nozzle.

The overall efficiency of the gas turbine engine is directly related to the temperature of the combustion gases, and as such, engine efficiency may be limited by the ability to operate the turbine nozzle at high temperature. As such, cooling engine components, including the turbine components, is necessary to facilitate reducing thermal stresses induced to such components. Accordingly, at least some known turbine nozzles include cavity cooling circuits which define flow paths for channeling cooling air flow through the cavity for cooling the airfoil, prior to the air flow being discharged downstream through trailing edge slots defined within the airfoil. Because of material limitations, known nozzle airfoils may require a complex cooling scheme to reduce operating temperatures within the airfoil.

BRIEF SUMMARY OF THE INVENTION

In one aspect, a method for securing a turbine nozzle is provided. The nozzle includes an airfoil having a suction side and a pressure side connected at a leading edge and a trailing edge such that a cooling cavity is defined within the airfoil. The airfoil extends between an inner band and an outer band. The method includes extending at least one member through the airfoil, and at least one of the inner band and the outer band. The method further includes securing the nozzle assembly in position with at least one fastener such that the at least one member is coupled adjacent to at least one of the inner band and the outer band.

In another aspect of the invention, a nozzle assembly for a turbine engine is provided. The nozzle assembly includes a plurality of nozzles that each include an outer band, an inner band and an airfoil. The airfoil has a suction side and a pressure side connected at a leading edge and a trailing edge, such that a cooling cavity is defined within the airfoil. The leading and trailing edges of the airfoil extend between the inner and the outer band. A member extends through said cooling cavity of said airfoil, and at least one of said inner band and said outer band. The member is secured within the nozzle assembly with at least one fastener such that the member is coupled adjacent to at least one of the inner and outer band.

In a further aspect, a turbine including a nozzle assembly is provided. The nozzle assembly includes a plurality of nozzles wherein each nozzle includes an outer band, an inner band and an airfoil. The airfoil has a suction side and a pressure side connected at a leading edge and a trailing edge such that a cooling cavity is defined within the airfoil. The airfoil extends between the inner and the outer band. A member extends through said cooling cavity of said airfoil, and at least one of said inner band and said outer band. The member is secured within the nozzle assembly with at least one fastener such that the member is coupled adjacent to at least one of the inner and outer band.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a schematic illustration of an exemplary turbine engine;

FIG. **2** is an exploded perspective view of a turbine nozzle assembly that may be used with the turbine engine shown in FIG. **1**;

FIG. **3** is an enlarged schematic cross-sectional view of a portion of the turbine nozzle shown in FIG. **2**;

FIG. **4** is a cross-sectional view of an airfoil that may be used with the turbine nozzle assembly shown in FIG. **2**; and

FIG. **5** is a cross-sectional view of an airfoil that may be used with the turbine nozzle assembly shown in FIG. **2**.

DETAILED DESCRIPTION OF THE INVENTION

FIG. **1** is a schematic illustration of a gas turbine engine **10** including a low-pressure compressor **12**, a high-pressure compressor **14**, and a combustor **16**. Engine **10** also includes a high-pressure turbine **18** and a low-pressure turbine **20**. Engine **10** has an intake, or upstream, side **28** and an exhaust, or downstream, side **30**. In one embodiment, engine **10** is a turbine engine commercially available from General Electric Power Systems, Schenechtady, N.Y.

In operation, air flows through low-pressure compressor **12** and compressed air is supplied to high-pressure compressor **14**. The highly compressed air is delivered to combustor **16**. Airflow from combustor **16** is discharged through a turbine nozzle assembly (not shown in FIG. **1**) that includes a plurality of nozzles (not shown in FIG. **1**) and used to drive turbines **18** and **20**. Turbine **20**, in turn, drives low-pressure compressor **12**, and turbine **18** drives high-pressure compressor **14**.

FIG. **2** is an exploded view of a turbine nozzle **50** that may be used with a turbine engine, such as engine **10** (shown in FIG. **1**). Nozzle **50** includes an airfoil **52** that extends between a radially outer band **54** having an outer surface **55** and a radially inner band **56** having an outer surface **57**. Each airfoil **52** includes a first sidewall **58** and a second sidewall **59**. First sidewall **58** is convex and defines a suction side of airfoil **52**, and second sidewall **59** is concave and defines a pressure side of airfoil **52**. Sidewalls **58** and **59** are joined at a leading edge **60** and at an axially-spaced trailing edge **62** of airfoil **52**.

First and second sidewalls **58** and **59**, respectively, extend longitudinally, in span between radially inner band **56** and radially outer band **54**. An airfoil root **64** is defined as being adjacent inner band **56**, and an airfoil tip **66** is defined as being adjacent outer band **54**. Additionally, first and second sidewalls **58** and **59**, respectively, define a cooling cavity **67** within airfoil **52**.

A first forward load transfer spacer **68**A and a first aft load transfer spacer **68**B are disposed within cooling cavity **67** and is adjacent airfoil tip **66**. A second forward load transfer spacer **70**A and a second aft load transfer spacer **70**B are disposed within cooling cavity **67** and is adjacent airfoil root **64**. In one embodiment, first forward load transfer spacer **68**A and first aft load transfer spacer **68**B form a single first load transfer spacer **68** and second forward load transfer spacer **70**A and second aft load transfer spacer **70**B form a single second load transfer spacer **70**. A first assembly plate **72** is coupled against outer band outer surface **55** and a second assembly plate **74** is coupled against inner band outer surface **57**. In another embodiment, first load spacer **68** and first assembly plate **72** are formed as one piece. In a further embodiment, second load spacer **70** and second assembly plate **74** are formed as one piece.

At least one member **76** extends through first assembly plate **72**, outer band **54**, first load spacer **68**, airfoil **52**, second load spacer **70**, inner band **56**, and second assembly plate **74**. In one embodiment, a pair of members **76** extend through first assembly plate **72**, outer band **54**, first load spacer **68**, airfoil **52**, second load spacer **70**, inner band **56**, and second assembly plate **74**. In the exemplary, members **76** are coupled in position using first and second load spacers **68** and **70** disposed within cooling cavity **67** and secured by fasteners, such as assembly nuts **77**, at either first or second assembly plates **72** and **74**.

FIG. **3** is an enlarged cross-sectional view of an assembled nozzle **50**. Members **76** are secured in tension, illustrated by arrows **80**, and airfoil **52** is secured in compression, illustrated by arrows **82**, by assembly nuts **77** fastened to at least one of first and second assembly plates **72** and **74**. When secured in position, members **76** facilitate sealing airfoil **52** between first assembly plate **72**, outer band **54**, inner band **56**, and second assembly plate **74** with a clamping force illustrated by arrows **84**. In one embodiment, members **76** have threaded ends to facilitate fastening assembly nuts **77** thereto. In another embodiment, at least one of first and second assembly plates **72** and **74** have a threaded opening sized to receive the end of member **76** allowing member **76** to extend substantially through at least one of first and second assembly plates **72** and **74**.

In one embodiment, airfoil **52**, and inner and outer segmented bands **54** and **56** are each formed of a material having a low strain to failure ratio, such as a ceramic material or ceramic matrix composite (CMC). In one embodiment, the CMC material is SiC—SiC CMC, a silicon infiltrated silicon carbide composite material reinforced with coated silicon carbide fibers. In one embodiment, ceramic material is a monolithic ceramic material such as SiC. More specifically, the material used in the fabricating of inner and outer bands **54** and **56** has a low thermal gradient capability, due to low strain to failure capability inherent to ceramics. In another embodiment, inner and outer segmented bands **54** and **56** are each formed of a low ductility material having a low tensile ductility.

First assembly plate **72** has an opening that permits air, illustrated by arrows **86** to enter nozzle **50**. First load transfer spacer **68** is adjacent airfoil tip **66** and is substantially positioned within a first cooling cavity **90** and a second load transfer spacer **70** is substantially positioned within a second cooling cavity **92** to provide a means for member **76** to secure airfoil **52** to nozzle **50**. In one embodiment, at least one of first load transfer spacers **68** and **70** have at least one opening allowing air **86** to enter first and second cooling cavities **90** and **92** of airfoil **52**.

FIG. **4** is a cross sectional view of airfoil **52**, airfoil includes a first spar **100** and a second spar **102** that is positioned between first spar **100** and trailing edge **62**. First spar **100** has a first side **104** and a second side **106** extending along a length **108**. First cooling cavity **90** is formed between leading edge **60** and first spar first side **104**. Second spar **102** has a first side **110** and a second side **112**. Second cooling cavity **92** is formed between first spar second side **106**, and second spar first side **110**. In the exemplary embodiment, airfoil **52** is formed having plys of CMC. As shown in FIG. **4**, ply splices are staggered in first spar **100**, such that, a splice **114** in first spar first side **104** is offset from a splice **116** in first spar second side **106**. Splices **114** and **116** are typically not positioned in high stress areas such as fillets.

In one embodiment, first and second sidewalls **58** and **59** have a variable thickness. First sidewall **58** has a thickness T1 that is greater than a thickness T2 of second sidewall **59** to accommodate a first pressure drop across the suction side that is greater than a second pressure drop across the pressure side. In one example, thickness T1 is approximately 0.15 inches and thickness T2 is approximately 0.1 inches. In another embodiment, first spar **100** has a varying thickness along length **108** of first spar **100**.

FIG. **5** is a cross sectional view of another embodiment of airfoil **52**. First and second sidewalls **58** and **59** have a constant thickness. In addition, ply splices are staggered in second spar **102** such that a splice **118** in second spar first side **110** is offset from another splice **120** in second spar second side **112**.

The above-described nozzle assembly is a cost-effective and efficient device. The nozzle assembly includes a member that facilitates securing an airfoil to the inner and outer bands, thus reducing an amount of time necessary to remove and replace a nozzle assembly. Furthermore, the member is more easily removably coupled to the nozzle assembly than other known nozzle mounting methods. As a result, the member facilitates extending a useful life of the nozzle assembly in a cost-effective and efficient manner by providing repairability or replacement of sub-components that may exhibit distress.

Exemplary embodiments of nozzle assemblies are described above in detail. The systems are not limited to the specific embodiments described herein, but rather, components of each assembly may be utilized independently and separately from other components described herein. Each nozzle assembly component can also be used in combination with other nozzle assemblies and turbine components.

While the invention has been described in terms of various specific embodiments, those skilled in the art will recognize that the invention can be practiced with modification within the spirit and scope of the claims.

What is claimed is:

1. A method for securing a nozzle assembly within a turbine engine, the nozzle assembly including at least one nozzle, the nozzle having an airfoil including a suction side and a pressure side connected at a leading edge and a trailing edge such that a cooling cavity is defined within the airfoil, the airfoil extending between an inner band and an outer band, said method comprising:

extending at least one member through at least one of a plurality of cooling chambers defined within the cooling cavity of the airfoil, and at least one of the inner band and the outer band; and

securing the nozzle assembly in position with at least one fastener such that the at least one member is coupled adjacent to at least one of the inner band and the outer band.

2. A method in accordance with claim **1** wherein at least one of the inner band, the airfoil, and the outer band is fabricated from at least one of a ceramic matrix composite material, and a monolithic ceramic material.

3. A method in accordance with claim **1** wherein securing the nozzle assembly in position induces tension in the member.

4. A method in accordance with claim **1** wherein extending at least one member further comprises extending a pair of members through the airfoil, and at least one of the inner band and the outer band.

5. A method in accordance with claim **1** further comprising:

positioning at least one load spacer within the cooling cavity; and

extending the at least one member through the at least one load spacer to secure the airfoil to the at least one of the inner and the outer band.

6. A method in accordance with claim **5** extending the at least one member through the at least one load spacer further comprises sealing the airfoil between the at least one of the inner and the outer band.

7. A nozzle assembly for a turbine engine, said nozzle assembly comprising:

an outer band;

an inner band;

an airfoil having a suction side and a pressure side connected at a leading edge and a trailing edge such that a cooling cavity is defined within the airfoil, said leading and trailing edge of said airfoil extending between said inner band and said outer band, said airfoil further comprising at least one spar extending between said pressure and suction sides for dividing said cooling cavity into at least two cooling chambers; and

a member extending through said cooling cavity of said airfoil, and at least one of said inner band and said outer band, said member secured within said nozzle assembly with at least one fastener such that said member is coupled adjacent to at least one of said inner and outer band.

8. A nozzle in accordance with claim **7** wherein at least one of the said inner band, said airfoil, and said outer band is fabricated from at least one of a ceramic matrix composite material, and a monolithic ceramic material.

9. A turbine nozzle in accordance with claim **7** wherein at least one fastener coupled to said member induces tension is said member.

10. A turbine nozzle in accordance with claim **7** wherein said member comprises a pair of members.

11. A nozzle in accordance with claim **7** further comprising at least one load spacer positioned within said cooling cavity, said member extending through said at least one load spacer to secure said airfoil to said at least one of said inner and said outer band.

12. A nozzle in accordance with claim **11** wherein said member seals said airfoil between said at least one of said inner and said outer band.

13. A turbine comprising:

a nozzle assembly having a plurality of nozzles, each nozzle comprising:

an outer band;

an inner band; and

an airfoil having a suction side and a pressure side connected at a leading edge and a trailing edge such that a cooling cavity is defined within the airfoil, said leading and trailing edge of said airfoil extending between said inner band and said outer band, said airfoil further comprising at least one spar extending between said pressure and suction sides for dividing said cooling cavity into at least two cooling chambers; and

a member extending through said cooling cavity of said airfoil, and at least one of said inner band and said outer band, said member secured within said nozzle assembly with at least one fastener such that said member is coupled adjacent to at least one of said inner and outer band.

14. A nozzle in accordance with claim **13** wherein at least one of the said inner band, said airfoil, and said outer band is fabricated from at least one of a ceramic matrix composite material, and a monolithic ceramic material.

15. A turbine nozzle in accordance with claim **13** wherein at least one fastener coupled to said member induces tension is said member.

16. A turbine nozzle in accordance with claim **13** wherein said member comprises a pair of members.

17. A nozzle in accordance with claim **13** further comprising at least one load spacer positioned within said cooling cavity, said member extending through said at least one load spacer to secure said airfoil to said at least one of said inner and said outer band.

18. A nozzle in accordance with claim **17** wherein said member seals said airfoil between said at least one of said inner and said outer band.

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